ANKLE KINEMATICS AND PLANTAR FASCIITIS IN RUNNERS: A ONE-YEAR PROSPECTIVE 4HAIE STUDY

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The aim of this prospective study was to compare ankle kinematics between runners with and without plantar fasciitis (PF). We biomechanically analysed 719 runners (17 PF and 702 non-PF) using a 3-D motion capture system during overground running at their self-preferred speed. An independent t-test was performed to assess ankle kinematics during the stance phase of running (at initial contact, at maximum and range of motion). Runners with PF displayed abduction ankle angle approximately 3º lower than the non-injured runners at maximal adduction (P = 0.006; d = 0.68). In conclusion, it appears that a higher ankle abduction (external rotation of the foot) may be a protective factor for PF. This information appears to be valuable for assessing running technique and may be beneficial to clinicians, coaches and runners who are afflicted with PF.

KEYWORDS: foot; ankle abduction; overuse injury; jogging

INTRODUCTION: Plantar fasciitis (PF), commonly known as "runner's heel," affects many recreational runners with an average incidence of 6% (Kakouris et al., 2021) causing intense heel pain. Despite its impact on daily activities, approximately 40% of runners continue running without a pause and less than 50% seek medical care (Wiegand et al., 2019). However, risk factors for PF still remain unclear, with potential factors including age, body weight, foot structure, biomechanics, footwear, and activity levels, but there is no consistent evidence across studies concerning the cause of PF (Wearing et al., 2006). Several studies have explored potential the biomechanical risk factors for PF such as the vertical loading rate (Johnson et al., 2020; Pohl et al., 2009; Ribeiro et al., 2015) and foot, ankle, and knee kinematics (Wiegand et al., 2022). However, all these suggestions were made based on investigations that were conducted retrospectively and these studies were unable to determine whether observed biomechanical differences between acute, chronic PF runners and healthy controls were cause or the consequence of PF. In addition, there is still a lack of research regarding 3D joint kinematics and PF. To address this research gap, the aim of our one-year prospective study was to examine ankle kinematics (discrete variables: at initial contact, at maximum and range of motion) as potential risk factors for PF in a large cohort of runners. We hypothesized that running biomechanics would influence the likelihood of PF diagnosis within a one-year follow-up.

METHODS: We analyzed 719 of the 1315 participants from the 4HAIE study (301 females / 454 males). The criteria for inclusion and exclusion for the 4HAIE study were outlined in the associated protocol paper (Jandacka et al., 2020). Briefly, participants were excluded if they had a musculoskeletal injury (including surgery or pain) or acute illness within 6 weeks before the baseline measurement, and if they reported history of PF. For the purpose of this study, we considered participants who ran regularly for at least six weeks and at least six km per week and did not drop out during 12 months follow-up. Consequently, we compared group of PF runners (N = 17; 8 females / 9 males; age = 38.8 ± 9.6 years; BMI = 22.3 ± 2.4; weekly running distance = 32.0 ± 13.3 km/week) and group of non-PF runners (N = 702; 277 females / 425 males; age = 36.9 ± 11.5 years; BMI = 23.9 ± 3.1; weekly running distance = 25.1 ± 17.4 km/week). Fourteen of PF injured runners were confirmed by medical professional and three self-reported PF without medical evaluation. Retro-reflective markers were positioned on the participant's right and left lower limb according to Visual 3D recommendations (C-motion, USA). A synchronized 3-D motion capture system containing 10 optoelectronic cameras (Qualisys, Sweden) and three force plates (Kistler, Switzerland) were utilized to collect kinematic (240 Hz) and kinetic (2160 Hz) data. All runners underwent an overground running measurement in laboratory neutral shoes within ± 5% of their self-preferred typical training speed. Eight successful running trials were required for the completion of data collection. Ground-reaction force and marker kinematic data were filtered using a fourth-order Butterworth low-pass filter with a cut-off frequency of 50 Hz (ground reaction force data) and 12 Hz (kinematic data). Foot model was defined by four calibration markers (placed on the lateral and medial malleoli, over the first and fifth metatarsal heads) and a triad of tracking markers over the heel. Ankle angles were determined as position of the foot relative to the shank using a Cardan rotation sequence Xyz. We did not use a virtual foot for the calculation of the ankle kinematics which is recommended for better clinical interpretation. However, the ankle angle in this study has the opposite orientation of the waveforms in the transverse plane. If we use a virtual foot for the calculation ankle angle calculation then the foot would move after initial contact in the abduction direction / external rotation (as can be seen in Figure 1). This note is important for the data interpretation later in this paper. Statistical analysis was performed in SPSS. Normality of the data was tested by Shapiro-Wilk test. An independent t-test was performed to assess ankle kinematics discreate variables (at initial contact, at maximum, and range of motion values) during the stance phase of running. The equality (homogeneity) of variances in the groups was tested by Levene´s test. Level of significance was set at 0.05 for all tests.

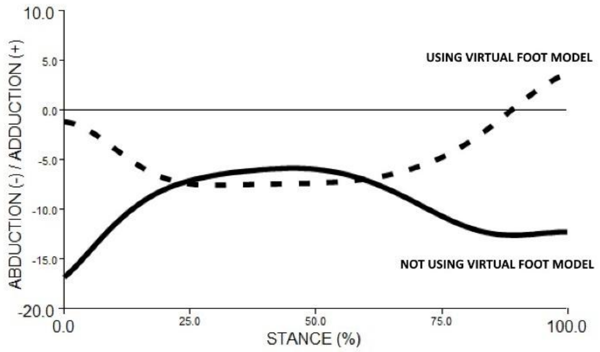

Figure 1: Example of ankle angle curves using different approach for kinematics calculation. Solid line – not using virtual foot, dot line – using virtual foot model.

RESULTS: A statistically significant differences was found in the maximal ankle adduction during stance phase of running. Injured runners with PF displayed higher values of ankle adduction than non-PF injured runners (Table 1 and Figure 2; *P* = 0.006; *d* = 0.68). All other kinematic variables in the ankle angle were non-significant.

Table 1: Comparison of kinematic variables between PF and non-PF runners

	PF	Non-PF	*P*	*d*
Sagittal plane				
Ankle angle at IC (+ dorsal flexion)	71.7 ± 8.7	71.8 ± 8.5	0.948	0.02
Maximal ankle dorsiflexion angle	86.2 ± 3.6	85.9 ± 4.2	0.749	0.08
Ankle ROM to maximal dorsiflexion	14.5 ± 8.8	14.1 ± 8.3	0.819	0.06
Maximal ankle plantar flexion	47.6 ± 6.5	46.8 ± 5.2	0.518	0.16

Frontal plane				
Ankle angle at IC (+ inversion)	-1.4 ± 7.6	-3.0 ± 6.4	0.324	0.24
Maximal ankle eversion	-14.4 ± 5.8	-15.4 ± 5.3	0.444	0.19
Ankle ROM to maximal eversion	-13.0 ± 4.8	-12.4 ± 4.7	0.635	0.12
Transversal plane				
Ankle angle at IC (+ adduction)	-16.9 ± 4.8	-18.6 ± 5.1	0.179	0.33
Maximal ankle adduction*	-5.3 ± 3.5	-8.1 ± 4.2	0.006*	0.68
Ankle ROM to maximal adduction	11.7 ± 4.3	10.5 ± 3.5	0.164	0.34

Note: Data are presented as mean and standard deviation. *P* – statistical significance for t-test (two-sided); *d* - Cohen´s d. OR – Odds ratio. IC – initial contact, ROM – range of motion. * *P* < 0.05.

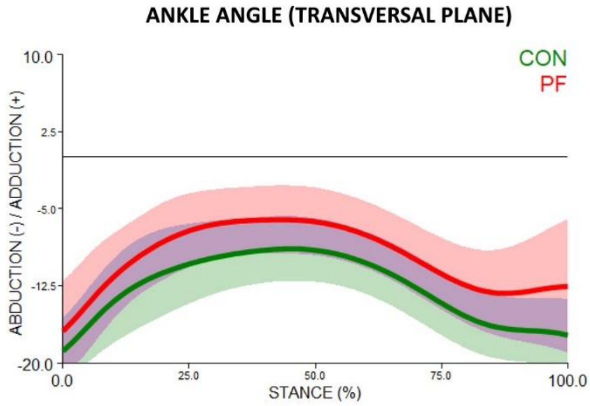

Figure 2: Right ankle angle (not using virtual foot for ankle kinematics calculation). Abbreviations: CON – runners without PF; PF – runners with PF.

DISCUSSION: The main aim of this prospective study was to compare running biomechanics between runners with PF and runners who did not suffer PF during one year follow-up. We hypothesized that the kinematics of the ankle angles would differ between injured runners with PF and runners without PF. We found a significant kinematic difference in the transverse plane angle of the ankle. Therefore, our hypothesis was partially confirmed. We found a significantly higher maximal ankle adduction in runners who did not suffer PF compared to injured group (i.e., lower abduction angle; or a lower maximum abduction angle if a virtual foot were used). Ankle abduction is a one component of the complex ankle motion called pronation that occurs with increasing dorsiflexion and eversion in the ankle after initial contact and reaches a maximum about 25-40% of stance phase during running which is the same time as the maximum of ankle abduction) (McClay & Manal, 1998). A term “pronation” is often inter-changeable with “eversion” (Nigg et al., 2015). An excessive pronation was extensively studied in late 20th and early 21th century as first running paradigm for overall running related injuries (Nigg, 2001). Pronation was also suggested as a potential risk factor for plantar fasciitis (Wearing et al., 2006). However, a cross-sectional retrospective study by Pohl et al. (2009) found no differences in ankle eversion/pronation between twenty-five female runners with a history of PF and group of 25 age and mileage matched runners without history of PF. Similar results for peak eversion/pronation angle during stance (i.e., no differences between groups) were reported in the study by Wiegand et al. (2022) where they cross-sectionally compared three groups of runners (acute, chronic PF and healthy controls). The results of the current study seem to be in the line with these two above-mentioned studies regarding the ankle angles in the sagittal and frontal planes.
Nonetheless, this study is the first to prospectively investigate three-dimensional ankle angle motion. It appears that a higher maximal ankle abduction angle, which naturally increases after foot strike along with increasing pronation, may be a protective factor for PF. However, for a

more comprehensive understanding, additional detailed analysis is still needed. For example, using binary logistic regression models that are able to control for sex, age, running distance etc. may be appropriate. In addition, to get a deeper insight, it would also be appropriate to use an analysis of continuous kinematic variables within a multi-segmental foot model and coordination patterns. Another limitation of the current study includes the fact that we did not collect information about foot arch. In addition, this study did not include data from clinical examinations such as passive ankle range of motion etc. While the use of uniform laboratory shoes ensured uniform testing conditions, the participants did not wear our laboratory-neutral cushioned running shoes during the one-year follow-up period.

CONCLUSION: This study showed that ankle motion in the transverse plane may play important role in risk for incurring PF. The maximal abduction ankle angle (increased external rotation of the foot) during stance phase may be potentially identified as a protective factor for PF. This information may be valuable to offer better insight to clinicians, coaches, and runners facing challenges with plantar fasciitis.

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